COST EFFECTIVENESS OF SELECTED ROADWAY DUST CONTROL METHODS FOR THE MENDENHALL VALLEY, JUNEAU, ALASKA

FINAL REPORT

by

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1. INTRODUCTION

The U.S. Environmental Protection Agency has set air quality standards for airborne particulates with diameters equal to or less than ten microns ("PM_{10}" particulates). These particulates have been correlated with respiratory illnesses. The standards for long term (annual) and short term (24 hour) PM_{10} concentrations are 50 and 150 micrograms per cubic meter, respectively.

The short term concentrations have been exceeded on several occasions in both Eagle River near Anchorage and in the Mendenhall Valley of Juneau. The Alaska Department of Environmental Conservation has undertaken a program to determine the sources of the particulates in these areas and potential ways to reduce them. This report is part of that effort.

A previous study (1)* estimated the quantities of emissions from various sources in both areas. This study is referred to in this report as "the inventory". Roadways, both paved and unpaved, were found to be the source of substantial amounts of particulates in both cases. This report presents the final results of an effort to determine the cost effectiveness of various strategies for reducing these particulate emissions from roadways in the Mendenhall Valley area. A companion report addresses the problem in the Eagle River.

An preliminary report for this study (2) presented rough estimates of the costs and benefits of a variety of emission reduction strategies. Of the strategies presented in that report, six were selected for more detailed analysis. Three of these are strategies for unpaved roads. These include:

- The use of surface application of asphalt emulsion as a dust palliative ("road oiling")
- The use of calcium chloride for the same purpose
- Paving

*numbers in parentheses refer to references listed in Section 6.

The other strategies apply to paved roads. These include:

- Paving driveways and other areas near paved roads (to reduce the amount of mud tracked onto the paved roads)
- Using "cleaner" sand as a winter traction aid
- A combination of the use of less sand and more effective spring cleanup

Strategies which were considered in the initial report but have not been given further examination include:

- Watering paved and unpaved roads during dry periods
- Using "Coherex" (a proprietary petroleum-derived dust palliative)
- In-place mixing of asphalt emulsion with the top several inches of roadway
- Substituting rock salt for winter traction sand
- Substituting calcium/magnesium acetate (CMA) for winter traction sand
- Vehicle speed restrictions on paved and unpaved roads
- Using heated sand to reduce the quantity of traction sand
- Regraveling unpaved roads at regular intervals

2. DISCUSSION OF THE PROBLEM

Only two air quality violations have been recorded in the Mendenhall Valley. These occurred on the 19th and 22nd of February, 1986. The monitoring site was at the Floyd Dryden School just off the Mendenhall Loop Road. During the same period fairly high particulate levels were recorded at a site at the Mendenhall Mall, although these did not exceed the standards (3). Nearly all of the roads in the vicinity of the school are unpaved, while most of those near the Mendenhall Mall are paved.

Weather records indicate that the air quality violations occurred during unusually dry weather. No precipitation was measured at the nearby Juneau airport between February 10 and 22, 1986, except for a trace on the 21st. Only .06" was measured between the 3rd and the 9th. As no airborne particulate violations have been recorded since that time, the problem in the Mendenhall Valley appears to be less severe than the one in Eagle River, where continuing violations have occurred.

3. LIMITATIONS OF THE STUDY

Both the costs and the benefits discussed in this report are defined in a very narrow manner. The costs given are only immediate construction or treatment costs; indirect costs are ignored. Calcium chloride, for example, increases corrosion of vehicles (although probably less when used for dust control than for melting snow). The calculated benefits are limited to air quality as measured by PM_{10} levels. Other benefits, such as lowered vehicle operating costs which result from paving roads, have not been considered.

Neither the estimates of costs or emissions reductions presented in this study are precise. J.M. Hoover, a leading authority on road dust control, has lamented that "quantitative measurements of dust from roads have been practically nil. Yet it is quite impossible and borders on the absurd to assess the economics and lasting value of dust palliation methods without monitoring the dust" (4, p.27).

This uncertainty was recognized in the emissions inventory, on which this study relied heavily. The inventory used the "best available techniques", yet for some important emissions categories this provided only "generally good order-of-magnitude" accuracy (1, pp. xii-xiii). Much of the difficulty in making estimates of emissions generation and reduction is that both are very dependant on site-specific soils types, weather, and other factors.

The costs of dust reduction methods are also variable. Road construction costs, for example, are dependent on local soils and drainage conditions, and to examine these on an individual street basis would far exceed the scope of the study. Emissions vary with traffic volume, yet traffic counts could not be performed on all of Mendenhall Valley's streets.

Estimates of emissions reductions were made for this report on an annual basis rather than a seasonal one. It should be noted that the best procedure for reducing annual emissions may not be the best for reducing the emissions in a particular season. Changes in the type and quantity of winter traction sand, for example, are more likely to affect springtime emissions levels than those in the fall.

4. SUMMARY OF FINDINGS

The estimated costs and emissions reductions are shown in Table 1. The figures for techniques applicable to unpaved streets are given on a per mile basis, while that for paved roads is given on an areawide basis. It should be noted that the emissions reductions listed are not additive, that is if two strategies are implemented simultaneously the benefit will not necessarily be the sum of the benefits of the two individually.

The figures shown for the paving of unpaved streets are based on paving a limited number of relatively high traffic collector streets. The figures shown for oiling or calcium chloride application, on the other hand, are based on an "average" unpaved street. The cost effectiveness of the latter two techniques would be more favorable if they also were applied only to selected busier streets.

The paving of driveways, lots, and street approaches to the main paved roads was examined for this report. The possibility of oiling or applying calcium chloride to these areas, however, was not. Based on the favorable cost effectiveness of these techniques as applied to unpaved roads, however, this might be a cost effective dust reduction strategy.

Table 1: Costs and Benefits of Selected Roadway PM_{10} Emission Control Techniques for Mendenhall Valley

Technique	PM_{10} Emissions Reduction (tons/year)	Cost ($/year)	Cost per ton ($)
<u>Unpaved Streets</u>			
1. Paving - 2" hot asphalt pavement (per mile) (Note 1)	50.7	25,360	500
2. Paving - Bituminous surface treatment (per mile) (Note 1)	50.7	19,700	389
3. Oiling Streets (per mile) (Note 2)	20.5	4,700	229
4. Calcium Chloride Application (per mile)	20.5	2,860	140
<u>Paved Streets</u>			
1. Paving Driveways, Lots, and Street Approaches (Note 3)	230.0	31,300	136
2. Use of Cleaner Sand (Note 4)	N/A	N/A	N/A
3. Reduced Sanding/Better Cleanup (Note 4)	N/A	N/A	N/A

Notes:

1. Figures are based on paving higher traffic (collector) roads (see text). Cost effectiveness would be reduced for paving of additional, less travelled roads.
2. Figures are based on the use of CSS-1 emulsified asphalt. If waste oils were available, costs would be reduced.
3. Figures are for paving areas adjacent to the Glacier Highway, Riverside Drive, and Mendenhall Loop (excluding the "back loop") only. See text for details.
4. The potential benefits were considered small and/or the technique was considered impractical in the Mendenhall Valley.

5. DETAILED FINDINGS

5.1 PAVING GRAVEL ROADS

To engineers a "pavement structure" usually means not only a road surface but the base and subbase layers of gravel. The word "pavement" as used in this report means just the waterproof road surfacing. Almost all pavements in Alaska are one of two types.

The least expensive of these is a "bituminous surface treatment", or BST. To build the most common type of BST, a layer of asphalt thinned with water ("emulsified asphalt") or a light petroleum product such as kerosene ("cutback asphalt") is sprayed onto a prepared gravel surface. Gravel screened to a uniform size ("chips", usually about 1/2 inch in diameter) is then spread over the asphalt and pressed into it with compactors. The asphalt hardens as the thinning agent evaporates out of it. A second layer of asphalt is then sprayed and a layer of smaller chips (about 1/4 inch in diameter) is applied. The resulting pavement is thin, but can be quite durable under light traffic if the underlying road embankment is strong and well drained. The BST described is the most common type in Alaska, but other types are possible using different size stones, a different number of layers, etc.

The other principal type of pavement used in Alaska is a "hot asphalt pavement", or HAP. This is also known by a confusing array of other names, such as asphalt cement concrete ("AC" or "ACC") or simply "hot mix". In this type of pavement the aggregate - a mixture of different sized sands and gravel - and the asphalt are both heated and mixed together in a central plant. The resulting mix is then trucked to the construction site and spread on the prepared roadway with a paving machine. The new pavement is compacted ("rolled") while still hot, and hardens upon cooling. The pavement layer is normally two to three inches thick, but in heavy traffic areas several layers can be placed to build up a thicker pavement. For the gravel roads in residential areas considered in this study, however, a minimum thickness would be needed.

Pavement Costs

Between two and three miles of road will probably be "strip paved" in Eagle River for the $400,000 budget available in 1988. The engineer's estimate for the final design of this work is about $153,000 per mile (5). The Eagle River program will include little other than a 2" layer of HAP. No significant improvements will be made to the road structure or drainage. This minimization of initial costs may result in higher than average maintenance costs on these roads in the future (5).

In contrast to the Eagle River program is that in the Mendenhall Valley, which is a similar residential community. Three "paving" projects will be built there in 1988 for about $525,000, including design, inspection, and administrative costs. The total amount of pavement, however, is equivalent to only about 1-1/3 miles of 24' wide roadway. One reason for the higher costs in Juneau is probably that there is less competition in the Juneau area than in the Anchorage area for construction work. These much higher "paving" costs, moreover, include substantial new drainage improvements, a lot of utility work (adjusting manhole elevations etc.), replacement of old culverts, seeding of bare soil, excavation, and miscellaneous other work.

These examples illustrate the difficulties of making a general estimate of paving costs. The examples do not even include many other expensive road improvements that are often made at the same time as paving. As long as the road is being paved, the argument goes, why not widen it? Why not straighten it? Why not add curbs and gutters, or sidewalks, or median strips? Why not plant trees? It is thus often difficult to isolate "paving costs" from historical records.

The table below presents estimated unit costs for work items associated with paving. The figures were developed from estimating factors used by the Juneau City/Borough (6). The cost of a BST is an exception; the figure cited is about 60% of the cost of a 2" HAP, an approximate ratio determined for Alaska in a previous DOT&PF study (7). The costs of engineering, inspection, and quality control by the contracting agency is estimated as 20% of the basic contract costs, and is included in the figures in the table.

Table 2: Unit Costs for Residential Street Paving

	ITEM	APPROXIMATE COST ($/square foot)
1.	Existing roadbed preparation	0.12
2.	4" crushed gravel base course	0.44
3.	Bituminous surface treatment (BST)	0.80
4.	2" hot asphalt pavement (HAP)	1.33
5.	Adjust manholes, catch basins etc.	0.15
6.	Excavation of poor material, per foot depth	0.30
7.	Common gravel fill (borrow), per foot depth	0.98

As the table indicates, the cost of the pavement itself may be only a fraction of the total project costs. As a minimum, the existing roadbed is normally prepared and a new base layer of several inches of high quality crushed gravel placed on the road.

The minimum paving costs including a new base course and utilities work (items 1, 2, 3, and 5 from the table) are equivalent to about $159,000 per mile for a BST 20 feet wide, which is a rather narrow pavement for a two lane road. BSTs, however, are not often used in the Juneau area. This is partly because successful construction of BSTs requires warm, dry weather, which is infrequent in the area. Successful construction also requires skilled, experienced personnel, which is lacking in the area (23).

A more common pavement for a residential street in the Mendenhall Valley would be a 2" hot asphalt pavement with at least a 24' width. A 24' wide HAP, using the figures from the table, would cost a minimum of about $259,000 per mile.

Major structural road improvements may also be needed. Thin pavements, especially BSTs, have very little strength in themselves. BSTs placed on thin, soft, wet embankments in Alaska have fallen apart completely during the first breakup. It may thus be necessary to raise the grade by as much as two or three feet, or to remove this much poor soils and replace them with better material. Estimated unit costs for such work are included in the table. New culverts, ditches, and other drainage improvements may also be necessary. The need for and cost of such improvements is very site specific and cannot be estimated on a unit cost basis. Such work, however, can cost several times as much as the pavement itself.

Utilities within the roadway add to the cost of paving. Most of the roads in the Mendenhall Valley have such utilities. Not only are manholes, catch basins, valve boxes, and the like, difficult to work around, but it may be necessary to adjust their height or rebuild them entirely. The amount of such work will vary, but can be expensive.

Drainage is often poor in the Mendenhall Valley area. A typical cost for upgrading and paving a road in the area might thus be about $421,000 per mile for a 24' wide surface. This includes $162,000 per mile in addition to the "minimum" cost given above. This amount would, for example, pay for excavation of 1' of poor material and a new 1' borrow layer (in addition to a 4" base and a 2" HAP) throughout the entire mile of road. It is more likely, however, that the additional money would be spent on a combination of excavation and borrow in selected areas, ditch and culvert work in others, etc.

For this report, it is assumed that $159,000 of the $359,000 is a permanent improvement while the remaining $200,000 has a 15 year life (that is the road will need repaving for $200,000 per mile every 15 years). Assuming a 4% real cost of money these capital expenditures are equivalent to an annual cost of about $24,360 per mile. Increased maintenance costs on a paved road may add about $1,000 to this figure, for a total cost of $25,360 per mile per year. If a BST with a 10 year life were used instead of HAP, this might be reduced to about $19,700 per mile per year.

Dust Reduction from Paving Streets

The inventory figure for PM_{10} fugitive dust emissions from paved local and collector streets is 99.7 tons per year, or 0.036 lb/VMT. The corresponding figure for unpaved roads is 0.410 lb/VMT. The implied emissions reduction from paving is 91% for each vehicle mile travelled.

The inventory's PM_{10} fugitive emissions estimate for unpaved local and collector roads averages 23.4 tons per mile annually. A 91% reduction from paving a mile of "average" gravel road would therefore be 21.2 tons annually. The emissions are dependent on traffic levels, however, and the first gravel roads to be paved will generally be those with the heaviest traffic, i.e., the "collector" roads.

Traffic counts have not been made on most streets in the Mendenhall Valley, so individual estimates for particular streets cannot be made. If one assumes that traffic on collector roads is 2-1/2 times as heavy as that on the local roads, then the PM_{10} emissions reduction from paving the collectors would be about 50.7 tons per mile. This is the figure used in this report. It is important to note, however, that it applies to the collector streets only. Paving a mile of local streets would reduce PM_{10} emissions by a lesser amount due to the smaller volume of traffic.

5.2 ROAD OILING

Road oiling can refer to a range of treatments using various materials. At its most extensive it refers to what was termed an "emulsion road mix" in the interim progress report prepared for this study (2). Here the top three or four inches of a gravel road are loosened, bladed into a windrow, and sprayed heavily with an oil, a cutback asphalt, or an emulsified asphalt. The material is then worked back and forth in the road to mix it thoroughly, spread and shaped to crown and grade, and then compacted. The result can appear almost like a pavement.

In this report, however, road oiling refers to a simple process in which a relatively small amount of oil is sprayed onto a damp road surface. This is done immediately after grading, while the surface gravel is still somewhat loose, so that the oil will penetrate farther.

In the past, waste oil (used crankcase oil, etc.) was frequently used for this purpose. This was both cheaper than using new oil and a convenient way to dispose of a waste product. Toxic materials were sometimes present in waste oil, however, creating a health hazard when sprayed on roads (the entire town of Times Beach, Missouri had to be abandoned for this reason). Waste oil must now be extensively tested before it can be used on roads, adding considerably to its expense. It is rarely used on roads any more. Therefore, only the use of new products are considered in this report (specifically slow-setting asphalt emulsions).

<u>Road Oiling Costs</u>

The Anchorage Public Works Department does a considerable amount of road oiling, which it refers to simply as "dust control". They apply 0.3 gallons of CSS-1 emulsified asphalt per square yard of road surface early in the summer. This provides adequate control for the summer on roads with relatively little traffic (8).

The Public Works Department estimates the labor and equipment costs to apply oil at about $425 per mile (9). This does not include the cost of grading the road, since it is assumed that the roads would be graded whether they were oiled or not. CSS-1 emulsified asphalt costs about $107 per ton in Seattle (10). Shipping costs to Juneau add about $70 to this figure (27) for a total of about $177 per ton. For a treated surface 24 feet wide, this is equivalent to about $3,100 per mile at 0.3 gallons per square yard.

The sum of labor, equipment, and material costs is thus $3525 per mile per application. It is assumed that two applications annually would be required on one third of the roads (the collectors), due to their heavier traffic and the wet weather in Juneau. This increases the cost of oiling to a system average of $4700 per mile annually.

<u>Dust Reduction from Road Oiling</u>

A number of sources discuss the use of road oiling as a dust suppressant (e.g., 4, 11, 12, 13). Most quantitative testing has been made at industrial sites with heavy truck traffic, which is not representative of the roads under consideration. They indicate, however, that results can be variable. Road oiling at a rate of 1/2 gallon per square yard on a low traffic public road in Arizona was found to be 96% effective at controlling dust one month after application, and was still 95% effective five months later (12). Another source (13) cites a test on a public road where oil mixed to a depth of several inches continued to be over 95% effective after several weeks.

Due to the reported variability of results and the smaller application rate assumed for this study, it is assumed that only 80% effectiveness would be achieved in the Mendenhall Valley. Average PM_{10} emissions for unpaved roads were found to be 25.7 tons per mile annually. An 80% reduction is therefore equal to 20.5 tons per mile annually.

5.3 CALCIUM CHLORIDE

Calcium chloride is a salt which has been widely used as a dust control agent on unpaved roads. It retards evaporation of water from the road surface and will also absorb water from the air at relative humidities above about 30%. Much of the dust reduction is thus achieved by keeping the road surface slightly damp. It also acts as a binder, producing a smooth, hard surface (although one which can still be graded if necessary).

Calcium chloride is supplied in flake or pelletized form. It can be spread in this form by sanding equipment, in which case enough water must be sprayed on the road to dissolve the salt. It may also be dissolved in water and applied with a water truck through a spray bar. It is normally applied immediately after road grading, and the road is usually compacted with a roller after treatment.

Calcium chloride has been used extensively in the Yukon Territory on higher traffic gravel roads. It has also been used for several years on city streets in Haines and some parts of the Dalton Highway. It has been tried in the Juneau area. Some Juneau observers feel that on weak, wet embankments calcium chloride makes rutting and mudiness problems worse (24).

Calcium Chloride Costs

On high speed roads (e.g., the Dalton and Alaska Highways) eight to ten tons of calcium chloride per mile are often used annually for dust control (14, 15). About half this much has proved adequate on slower speed roads. About 3-1/2 tons per mile are used in Haines, with selected areas requiring a second treatment at this rate late in the summer (16). For this report the 3-1/2 tons per mile rate is assumed; it is further assumed that one third of the roads would require two applications per year. Recent prices for calcium chloride delivered to DOT&PF maintenance stations have been about $450 per ton in 2,000 pound bladders and about $500 per ton in 80 pound sacks (17). The latter price is assumed here, yielding an average material cost of $2,325 per mile annually.

Labor and equipment costs are estimated to be about $400 per mile per application, or an average of $535 per mile annually. This is based on typical "Rental Rate Blue Book" (18) costs for two water trucks and a roller, two operators at $25 per hour (including benefits, overhead, etc.) and a foreman at $30 per hour. A grader and a third operator would also be required, but these costs are not counted as it is assumed that the road would be graded anyhow. This is the crew size and equipment used in Haines. Productivity is assumed to be 2 crew-hours per mile, also about what has been reported in Haines (16) and slightly less than road oiling crew productivity estimated for Anchorage (9).

Dust Reduction from Calcium Chloride

A number of sources discuss the use of calcium chloride for dust suppression. Most quantitative measurements have been made at industrial sites whose conditions are not similar to those on the roads in the Mendenhall Valley. One source (11) which reports on a calcium chloride test on a low traffic public road indicates that over 90% effectiveness was maintained for an extended period. Another source (13) cites a test where calcium chloride treatment of a public road was 74% effective after several weeks. The effectiveness in Haines has not been measured quantitatively, but it is reported that the treatment gives "almost complete" dust control (16). For this report it is assumed that calcium chloride effectiveness is 80%, the same as road oiling. This is equivalent to 20.5 tons per mile of PM_{10} emissions reduction annually.

5.4 PAVING DRIVEWAYS, LOTS, AND GRAVEL STREET APPROACHES

Substantial dust can be generated on paved roads if they are dirty from having mud and debris tracked onto them from unpaved areas. The calculations made for the emissions inventory for the Mendenhall Valley, for example, indicated that dust generated per vehicle mile travelled on dry, dirty, sanded, paved roads in springtime are about 1,000 times as great as they are on the same roads after sweeping. It is clear that if "carryout" mud can be reduced dust emissions on paved roads will be greatly reduced.

One strategy for reducing dust emissions, then, is to pave what are currently unpaved approaches to the high traffic roads in the area. These approaches include driveways, parking lots, and intersecting streets. Paving the intersecting streets for the first 100 feet, for example, could greatly reduce mud carryout, although some amount of mud may be carried for as much as 1000 feet (19).

The streets in the Mendenhall Valley included in this "high traffic" category for this report include Glacier Highway, Egan Drive, Riverside Drive, and the eastern part of Mendenhall Loop Road between Egan Drive and the Mendenhall River bridge.

Cost of Paving Driveways, Lots, and Gravel Road Approaches

The cost per square foot of placing pavement on small areas like driveways is more than that for paving entire roads. On the other hand, much less associated work is generally needed since strength requirements are less and drainage is usually less of a problem. Typical costs to provide some gravel base material and pave drives and small lots are about $1.50 to $2.00 per square foot (20, 21). For a small residential driveway (12' wide and 60' long) this translates to about $1250.

For this report it is assumed that paving costs are $1250 for small driveways, $2500 for larger, commercial driveways, and $5000 for an apron on a gravel road extending 100 feet back from the paved road. Paving entire parking lots was not considered necessary. Each entrance to such lots was counted as a commercial driveway. An inventory made of these features along "arterial" roads in the Mendenhall Valley is summarized below.

Table 3: Inventory of Unpaved Areas Adjoining Major Paved Roads in the Mendenhall Valley

Road	Number of Unpaved Approaches		
	Residential	Commercial	Streets
Glacier Highway/Egan Drive (between the western intersection with Mendenhall Loop and Lemon Road)	33	9	5
Mendenhall Loop (eastern side between Egan Drive and Mendenhall River Bridge)	33	8	19
Riverside Drive	23	6	12
Total	89	23	36

The cost to pave all these areas is estimated at $348,000, over half of which is for the street approaches. Assuming a 4% real cost of money and a 15 year life, this is equivalent to a $31,300 annual cost.

Dust Reduction from Paving Drives, Lots, and Street Approaches

The inventory estimated PM_{10} fugitive dust from the arterial roads to be 704.3 tons per year. This included the western part of Mendenhall Loop (the "back loop") which was not counted here. The back loop carries about 4% of the total traffic on the arterials (22); fugitive dust excluding this is 676.1 tons annually. It is estimated that about a third of this may come from sanding material. The remainder, 451 tons per year, is assumed to come principally from mud carryout.

It is difficult to estimate how effective the suggested program would be at reducing mud carryout; no good guidelines have been found in the literature. If one assumes that it would reduce mud tracked onto these major roads by 75%, the reduction in PM_{10} emissions would be 338 tons per year.

In reality this program would have no substantial effect on emissions from Egan Drive east of Mendenhall Loop Road, which accounts for over 30% of the vehicle miles travelled on the major roads considered here (22). The argument can therefore be made that mud carryout onto this part of the road system should neither have contributed to the emissions inventory nor can it be reduced by the program considered here. If calculations are adjusted based on this reasoning, the initial inventory emissions were overestimated by 144 tons per year, while the emissions reduction listed above is overestimated by 108 tons. An adjusted emissions reduction figure of 230 tons is used in this report.

5.5 CHANGING SANDING MATERIAL SPECIFICATIONS

Dust sized particles may be present in sanding material when it is applied, or they may be produced by the breakdown of larger particles under the effects of traffic. The harder and more durable the material, the less likely it is that the latter will occur. Unfortunately, standard laboratory tests for durability apply only to coarse sand and larger particles. Durability specifications therefore would have no influence on most of the sanding material applied in the Mendenhall Valley by the DOT&PF (unless new tests were devised). Harder material, moreover, would be more abrasive to pavements, producing more dust-sized particles from that source. It is thus unclear that durability specifications would have a large effect on airborne particulates.

Size specifications (gradations) do apply to small particles, however, and can be changed. Testing is normally performed by passing material through a set of sieves, the smallest of which (#200) has an opening size of 75 microns. In order to test for smaller particle sizes (such as 10 microns), a different and more expensive hydrometer test must be performed on the finer material. If little material smaller than 75 microns is allowed, of course, there will be even less material smaller than 10 microns present, so the hydrometer test is probably unnecessary for dust control purposes.

The amount of fine particles allowed in sanding material is already quite limited by both the City/Borough of Juneau and the DOT&PF in Juneau. The gradation requirements of both are shown in Table 4. The City/Borough uses a pea gravel, and specifies that less than 1/2 of 1% of the material will pass a #200 sieve. The DOT&PF uses smaller gravel and sand, which has been found to cause less windshield damage on higher speed roads (26), and allows a maximum of 5% "fines". The material received by DOT&PF last winter generally contained only 2 or 3% (21). The supplier had to wash both materials in order to meet the specifications (25).

Table 4: Sand Specifications - Mendenhall Valley

Sieve Size	Percent Passing: City/Borough	Percent Passing: DOT&PF
3/8"	90-100	100
#4	40-80	
#8	8-12	
#16		0-50
#200	-0-	0-5

Note: The openings on #200 sieve are about 75 microns

It seems clear that there would be little benefit to changing gradation specifications for sanding material in the Juneau area, and this strategy was not considered further. Such changes were found feasible, however, for the companion study on the Eagle River area.

5.6 REDUCED SANDING AND BETTER CLEANUP

The less sand that is used as a winter traction aid, and the sooner it is cleaned up in the springtime, the smaller the dust emissions from this source will be. The Eagle River Road Service Area has greatly reduced their use of winter traction sand in the past two years and has also begun sweeping local streets in springtime, which they had not done before. The possibility of making similar changes in the Mendenhall Valley to reduce PM_{10} emissions was therefore included as part of this study.

In the case of Eagle River, sanding material for local roads used to be supplied by a maintenance contractor, who was paid for it and its application according to the amount that was used. Furthermore, the material used at that time was of poor quality, and a lot of material was needed to provide effective traction (25). Both of these tended to increase sand usage. The local roads authority found they used much less sand once they began providing their own, higher quality material.

The City/Borough of Juneau already provides their own, clean sanding material, and already performs street sweeping. When asked about the possibility of making improvements in these areas, they responded:

> Any reduction in sanding could create a liability problem that is insurmountable. As far as clean-up, Juneau is a very tourist oriented town and it has been and will continue to be our policy to begin our clean-up operations as early as weather permits. This however does require that the temperature be above freezing as our sweepers require water to prevent damage to the intake fan. Also of course, we can not flush streets when there is a danger of freezing occurring. (24)

The response of the DOT&PF was similar to the one given above by the City/Borough.

It would be possible to operate tractor or loader mounted brooms (which do not use water) before thawing temperatures prevailed to remove some sand and debris not frozen in place. Since dust is generally not a problem this early in the year, however, this procedure was not considered for this report.

It has been noted that driveways are generally not swept in the spring street sweeping operations, and suggested that road crews might sweep off an apron area of driveways. This might result in a modest reduction in the amount of material tracked out onto roadways for a relatively modest cost. This possibility was not examined in detail for this report.

6. Short-term (24 hour) Emissions Reductions

Short-term particulate levels are of primary interest in the Mendenhall Valley, as it is this air quality standard which has been exceeded. An attempt is therefore made here to evaluate the effects of the selected treatments on "worst-case" 24 hour PM_{10} emissions.

These "worst-case" emissions as determined by the inventory by season are shown in Table 5. The table indicates that spring and fall are the worst seasons, followed by summer. Winter "worst-case" emissions are estimated to be only a tenth of those in summer. The only recorded violations of the air quality standard, however, were in late February of 1986 (see Section 2). The inventory thus does not appear to adequately explain the short term emissions which led to these violations.

TABLE 5

WORST-CASE 24-HOUR EMISSIONS BY SEASON
MENDENHALL VALLEY

(tons/day)

Source Category	Spring		Summer		Fall		Winter	
	PM_{10}	TSP	PM_{10}	TSP	PM_{10}	TSP	PM_{10}	TSP
Paved Streets - Fugitive Dust	21.45	51.36	0.49	1.24	21.45	51.36	0.49	1.24
Unpaved Streets - Fugitive Dust	0.08	0.23	9.13	20.28	0.08	0.23	0.08	0.23
Windblown Dust	11.51	23.00	11.51	23.00	11.51	23.00	N	N
Woodstoves and Fireplaces	N	N	N	N	N	N	1.32	1.32
Others	0.33	0.68	0.21	0.24	0.21	0.24	0.21	0.24
TOTAL	33.37	75.27	21.34	44.76	33.25	74.83	2.10	3.03

N = Negligible

Note: This table is reproduced from the inventory report (Reference 1).

Furthermore, the inventory indicates negligible fugitive dust emissions from unpaved streets during spring and fall "worst case" conditions. The estimate for emissions from this source is more than 100 times as great in summer. The worst dust problem on unpaved roads occurs after prolonged periods of dry weather. While such weather may be more likely in Juneau in summer, it seems clear that as a "worst case" it may also occur in other seasons - even winter, as happened during the days leading up to the violations.

The inventory also indicates that fugitive dust from paved roads dominates the "worst-case" emissions in both spring and fall. The high estimate of spring emissions results from the assumption of large amounts of sanding material and other debris on the roads. The high levels indicated in fall from this source are apparently an error, as the inventory text states that "for the remainder of the year when roads are sand-free", a different emissions estimating methodology was used (1, p. 2-11).

Given the uncertainties regarding the quantitative estimates of short-term emissions generation, there can be only limited confidence in quantitative estimates of short-term emissions reductions. Nonetheless, such estimates have been made. These are based on the following major changes in the assumptions used in the inventory:

- It is assumed that short-term fugitive dust emissions from unpaved roads may be as high in spring and fall as was estimated in the inventory for summer.

- It is assumed that high levels of short-term fugitive dust emissions from paved roads occur only in the spring, and not also in the fall as is indicated in the inventory.

Given these assumptions, the highest levels of "worst-case" short-term emissions will occur in the spring. The estimated emissions reductions for this season are summarized in Table 6 based on the following:

Table 6: Costs and Benefits of Selected Roadway PM_{10} Emission Control Techniques ("worst case" 24 hour period)

Technique	PM_{10} Emissions Reduction (tons/24 hr)		Cost ($/year)	Cost per ton ($)	
	Collectors	Local		Collectors	Local
Unpaved Streets					
1. Paving - 2" hot asphalt pavement (per mile) (Note 1)	0.524	0.086	25,360	48,400	295,000
2. Paving - Bituminous surface treatment (per mile) (Note 1)	0.524	0.086	19,700	37,600	229,000
3. Oiling Streets (per mile) (Note 2)	0.124	0.025	4,700	37,900	188,000
4. Calcium Chloride Application (per mile)	0.204	0.041	2,860	14,000	69,800
Paved Streets	Systemwide			Systemwide	
1. Paving Driveways, Lots, and Street Approaches (Note 3)	5.01		31,300	6,250	
2. Use of Cleaner Sand (Note 4)	N/A		N/A	N/A	
3. Reduced Sanding/Better Cleanup (Note 4)	N/A		N/A	N/A	

Notes:
1. Figures are based on paving higher traffic (collector) roads (see text). Cost effectiveness would be reduced for paving of additional, less travelled roads.
2. Figures are based on the use of CSS-1 emulsified asphalt. If waste oils were available, costs would be reduced.
3. Figures are for paving areas adjacent to the Glacier Highway, Riverside Drive, and Mendenhall Loop (excluding the "back loop") only. See text for details.
4. The potential benefits were considered small and/or the technique was considered impractical in the Mendenhall Valley.

6.1 Paving Gravel Collector Roads

The inventory's estimate of "worst-case" PM_{10} emissions from unpaved collector roads is 2,155 lbs per thousand vehicle miles travelled (1,000 VMT). For unpaved local roads, lower assumed traffic speeds resulted in a lower emissions estimate of 1,078 lb/1,000 VMT. The "worst-case" emissions for paved roads in the spring (before street sweeping) is 330 lbs/1,000 VMT. The implied reduction is therefore 1,825 lbs/1,000 VMT for collector roads and 748 lbs/1,000 VMT for local roads.

Daily traffic on unpaved collector and local roads was estimated for the report to average 574 and 230 vehicles per day respectively (see Section 5.1). Based on this traffic level, the PM_{10} emissions reduction under spring "worst-case" 24 hour conditions is 1,047 lb. per mile for the collector roads and 172 lb. per mile for local roads.

6.2 Road Oiling

PM_{10} emissions reduction from road oiling was assumed to be 80% for the long term estimate. For the "worst case", however, it is assumed that gravel roads are graded in the fall just before freezeup. Grading destroys much of road oiling's dust palliation effect. The "worst case" is assumed to occur in spring before the roads are re-oiled, and the reduction at this time is estimated at only 20%, or 247 and 50 lb. per mile in 24 hours for collector and local roads, respectively.

6.3 Calcium Chloride

Grading destroys much of calcium chloride's beneficial effects, as it does with road oiling. Unlike road oiling, calcium chloride will recover some of its effectiveness over time. Some recovery is assumed to occur between fall grading and the early spring "worst case"; a 33% PM_{10} emissions reduction is estimated, or 408 and 82 lb. per mile in 24 hours for collector roads and local roads respectively.

6.4 Paving Driveways, Lots, and Gravel Street Approaches

This procedure affects emissions from arterial roads. The inventory estimates an annual average PM_{10} emission factor of 41.5 lb/1,000 VMT for these roads. This is equivalent to 15.1 lbs. per mile annually for each vehicle of average daily traffic (i.e., per 365 VMT). The corresponding figure for the "worst case" 24 hours is 0.33 lb. per VMT. This implies 2.2% of the annual total occurs on the worst day.

The annual total PM_{10} emissions reduction for this procedure was estimated in Section 5.4 to be 230 tons; the "worst case" 24 hour reduction is estimated to be 2.2% of this, or 5.01 tons (10,020 lbs.)

6.5 Changing Sanding Material Specifications, Reduced Sanding and Better Cleanup

No significant 24 hour emissions reductions were considered likely in Mendenhall Valley from practical measures in these areas, as was true of annual emissions.

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